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ABSTRACT

Presented are guidelines established by the Texas Education Agency to aid Texas school administrators, teachers, and architects in upgrading existing science education facilities and in planning new facilities in public school classrooms, kindergarten through grade 12. Equipment and facility needs are organized around activities listed for elementary, middle, junior high, and high school science programs. A laboratory safety checklist and sample plans for new construction of science laboratories and classrooms are also included. (CS)

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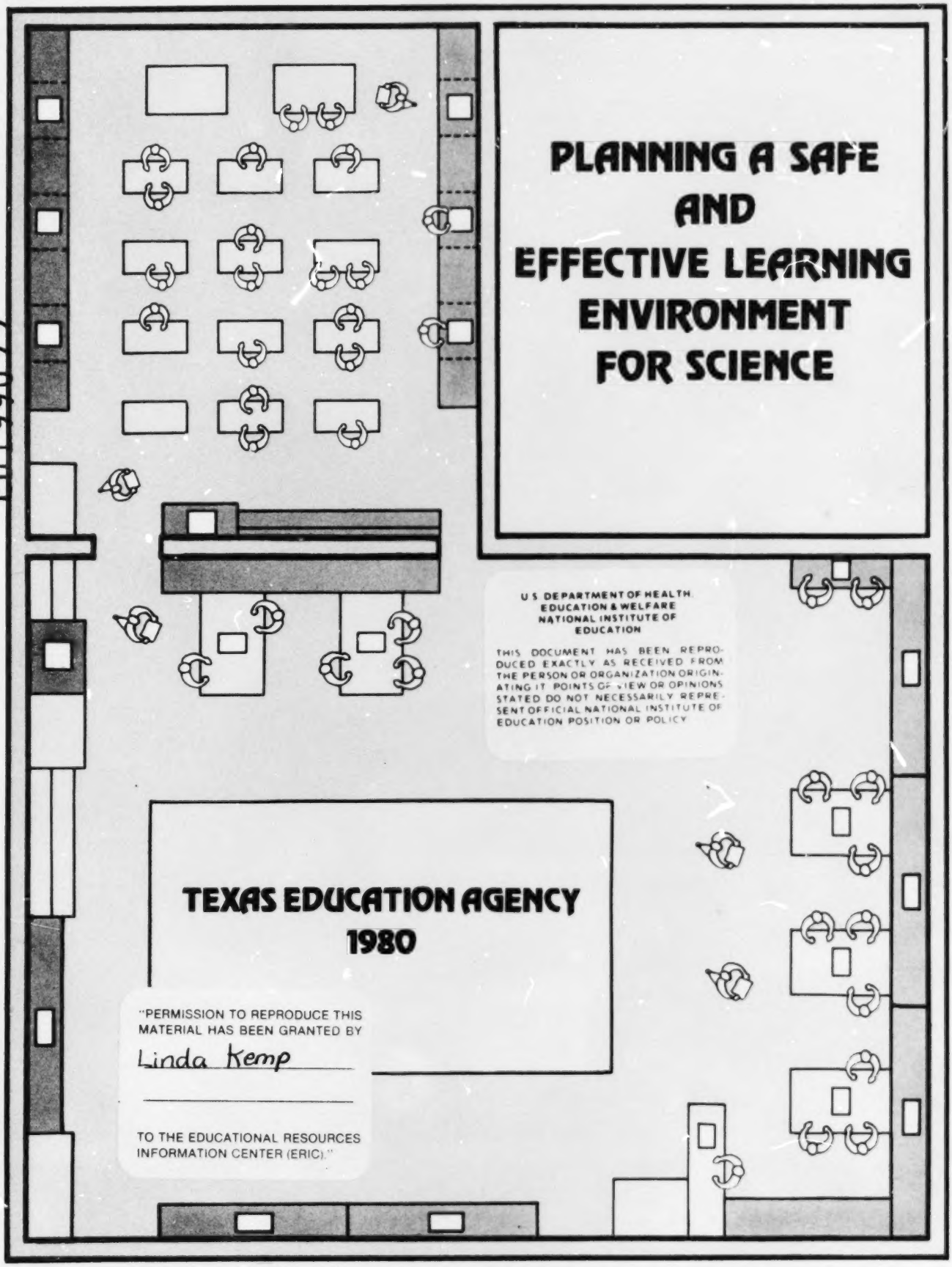

PLANNING A SAFE AND EFFECTIVE LEARNING ENVIRONMENT FOR SCIENCE

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Austin, Texas

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Foreword

These guidelines, *Planning a Safe and Effective Learning Environment for Science,* have been prepared to aid Texas school administrators, teachers, and architects in upgrading existing science education facilities and in planning new facilities, kindergarten through Grade 12.

The guidelines are a revision of a 1971 publication developed by a committee of public school science supervisors and university educators. The guidelines give suggestions and designs to help schools provide facilities to enable students to experience scientific phenomena, thus increasing their perceptions of the technological world in which they live.

We hope these guidelines will encourage the proliferation of safe and effective science programs that stress laboratory activities and analytical thinking.

Alton O. Bowen
Commissioner of Education

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Acknowledgments

A writing committee of science educators developed the original version of these guidelines, published in 1971. Members of the committee were:

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Members of the science section of the Division of Curriculum Development, Texas Education Agency, assisted the writing committee and now have revised the original publication for the current printing.

Appreciation is expressed to those who contributed their ideas, efforts, and experience to the development of the publication. Special recognition is given to John Buford, a physical engineer with Structural Associates of Houston. While an architectural engineering student at The University of Texas at Austin, Mr. Buford sketched the floor and furniture plans for the publication.

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Overview of the Science Program

WHY TEACH SCIENCE?

Society's charge to the schools is to prepare students for today's world and to help them move into the future as responsible members of a changing, highly technological world. Science, therefore, is an important part of the educational program, for even the layperson today must have a working knowledge of science and technology. For these reasons, science courses are required in Texas public schools.

WHERE IS THE EMPHASIS IN SCIENCE INSTRUCTION?

The organized body of scientific facts has become so voluminous that it would be impossible for any individual to learn it all in a lifetime. The investigative processes of learning, however, remain essentially unchanged; therefore, it is necessary that science be presented as an integration of these processes, which include:

- observing
- classifying
- measuring
- communicating
- inferring
- recognizing space-time relations
- recognizing number relations
- predicting
- controlling variables
- interpreting data
- defining operationally
- experimenting

Policies approved by the State Board of Education of Texas require that all science courses, Grades 7-12, be laboratory oriented. Moreover, science educators agree that the laboratory approach should be initiated upon the first contact with the science program in the primary grades and continued throughout the educational life of the student. Learning experiences should occur in a laboratory situation where students can use the processes of learning in developing their manipulative skills and analytical thinking.

WHAT KIND OF ENVIRONMENT IS REQUIRED FOR PROCESS-ORIENTED INSTRUCTION?

The story of the sciences and the laws that govern them can readily be told; however, this approach to teaching science relies mainly on memorization and usually is lacking in depth of perception.

Through a three-phase teaching technique of pre-laboratory introduction, laboratory activity, and post-laboratory discussion, students can be led to discover how basic laws and principles of science are manifested. (For example, see *Life Science: An Activity Guide,* TEA Publication CU1 832 02.) The students explore the scientific world in a variety of activities. They find that science is not merely a verbal explanation of isolated theories and facts, they discover that the basic concepts of science are generalizations with wide applicability and that these concepts may interweave through language arts, social studies, mathematics, and fine arts.

Adequate time, sufficient work space, and proper equipment are essential for successful student activities. The time factor and the kinds of equipment needed will be determined by the types and levels of activities to be conducted within the facility. Because science teachers plan the laboratory activities, they should also help plan the facilities.

The modern science classroom is more than a place for desks and chairs. It is a well-equipped laboratory-classroom with sufficient space and equipment for investigations to be done individually or in small groups. Students are encouraged to use the equipment and to personally observe the phenomena, record data, and make inferences—thus enhancing their ability to reason and adding the job of discovery to the satisfaction of achievement.

A minimum of 45 square feet per student is necessary in the combination laboratory-classroom designed to serve a class of 24 secondary science students. In addition, a minimum of 15 square feet per student should be allowed for storage and preparation. A rule of thumb is to allow a minimum of 60 square feet per student, calculated on the maximum number of students to be served by the facility at any one time.

WHAT ARE THE EXPECTED OUTCOMES OF A SUCCESSUL SCIENCE PROGRAM?

Effective science teaching in a proper laboratory environment can contribute to students' development of:

- a curiosity leading to a satisfying understanding of the scientific-technological world in which they live
- an idea of the scope of scientific descriptions and interpretations
- an awareness that there are underlying unifying principles of science that interweave through all academic areas
- an appreciation of the historical development of science
- a recognition that the processes of science permit a balance between quantitative and qualitative knowledge
- a capacity for objective judgment and critical thinking

Elementary Science Facilities

RATIONALE

One of the unifying themes found throughout the continuum of science experiences from kindergarten through Grade 12 is the inquiry approach. This approach provides students with the techniques and thought processes that will satisfy their natural curiosity for learning.

Learning from involvement with equipment and from interaction with classmates is central to the teaching of science. In the laboratory environment, the student relates concepts and processes as a means of exploring ideas. Initial experiences with science should involve the child in experimental investigation. Skills in such basic process as observing, measuring, classifying, using numbers, inferring, and communicating should be introduced early and practiced as routine class activities.

The use of the laboratory investigative method of teaching preserves the natural curiosity of children, prepares them for the transition to later science courses, and helps them develop skills useful in other study areas. It is within the informal, small-group activities of elementary science that young students learn to appreciate and to enjoy science and the processes used by scientists. It is here that the stimulus to continue to learn science as an integral part of basic education is initiated.

ACTIVITIES

Science, K-Grade 3. In keeping with guidelines in Texas Education Agency Publication CU9 841 01, *Elementary Science Resource Guide,* activities are organized around the processes of learning science: observing, inferring, predicting, using numbers, measuring, using space-time relations, communicating, and classifying. Most activity should be performed by students organized into small sections. Some typical examples of small group activities are:

- collecting and classifying rocks, leaves, and seeds
- observing animal and plant motion
- setting up and maintaining aquaria
- constructing a terrarium
- measuring length, volume, mass
- ordering sticks by size
- observing growing plants
- constructing and using classification systems
- constructing carts with wheels of different diameter
- observing life cycles of insects

- recording data on graphs
- maintaining weather charts
- searching for patterns

Figure I.1. A primary room is furnished with two-student tables and a counter along the wall.

Science, Grades 4-6. In addition to processes listed for K-Grade 3 science, more complex processes are introduced in Grades 4-6: controlling variables, interpreting data, formulating models, formulating hypotheses, and experimenting. Within the framework of these combined processes, the student develops a feeling for the inquiry approach. The interaction afforded by students working in small groups provides an optimum of interest and participation. Sample activities are:

- studying behavior patterns of animals
- conducting polls
- determining variables in motion studies
- determining growth factors of plants and animals
- interpreting photographs
- studying force and motion relationships
- constructing models
- constructing astronomical instruments
- experimenting with magnets and electricity

- classifying rocks and minerals
- measuring mass, volume, distance
- using a microscope and making micromeasurements
- assembling skeletons, puzzles
- observing chemical reactions

Figure I.2. Individual movable tables lend maximum flexibility to an intermediate room.

FACILITIES

Since the science activities in K-Grade 3 and in Grades 4-6 differ only in complexity, a single type of facility is adequate for both groups.

All current curricular materials for elementary school science have two factors in common: they involve students working in small groups as routine class procedure and they require the teacher to become a "learning engineer." These represent changes in procedure. They require more storage than was formerly necessary (six sets of equipment where there used to be one, for example) and a more specialized classroom to facilitate the experiences characteristic of the new materials.

Minimums for Elementary Science Area

The minimum requirements for an elementary science area are:

- 30 square feet of floor space per student, including storage
- movable individual or two-student tables
- counter space including one sink

- light control on all openings
- ample shelving and/or closets
- shelving or tables to store equipment in use
- provisions for audiovisual equipment
- bulletin board and chalkboard
- electrical outlets spaced for convenient use
- aquarium, animal cages, incubator
- fire extinguisher

Figure I.3. Basic requirements of a primary room include sink, storage, and project area.

Desirable Items

In addition to the minimum requirements, the following items are desirable and should be provided for an optimal program:

- operable partitions between rooms
- protected "growing place" in school yard
- simple greenhouse which may be portable
- vivarium

- work table with simple hand tools
- a window in the classroom for growth projects
- storeroom with shelves, file cabinet, and equipment preparation areas

All rooms in the elementary school do not have to meet these requirements; however, there should be a sufficient number so equipped that by an exchange of rooms science can be taught in this environment.

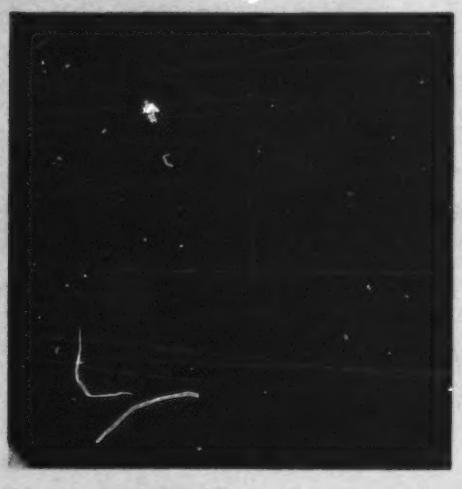
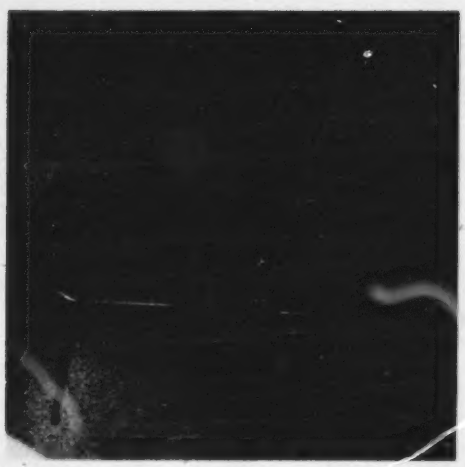


Figure I.4. Chair desks with horizontal work surfaces invite flexibility by providing for different arrangements.



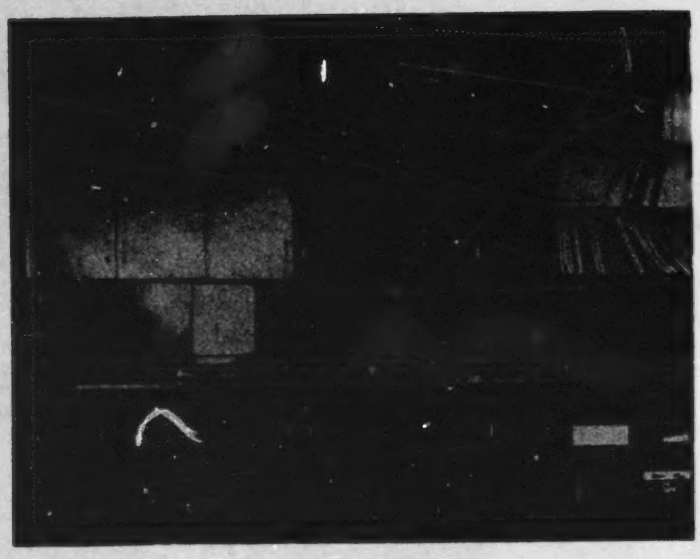


Figure 1.5. Storage and materials preparation areas encourage student activity.

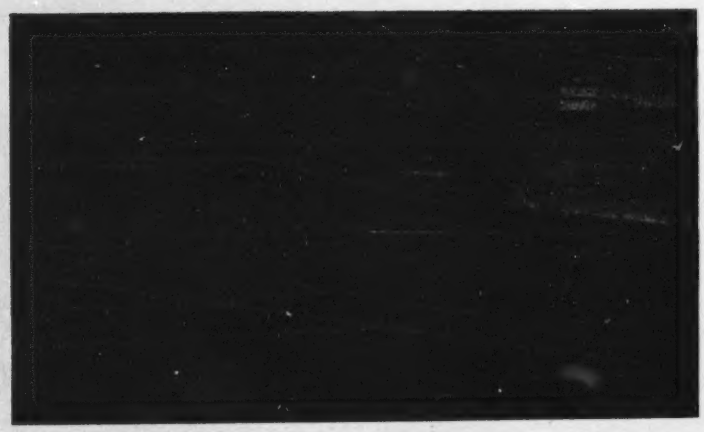


Figure I.7. Project area with additional storage and shelving for reference materials promotes interest in individual project work.

Middle School Science Facilities

RATIONALE

A number of Texas school districts are moving toward a pattern of establishing middle schools, usually Grades 6-8, and it is reasonable to assume that more will follow. Therefore, the impact of the middle school on planning must be considered.

The middle school must stand by itself as a division that is concerned with students at their existing stage of development and that relates its programs to students' past and future experiences.

The development of the processes of science is begun in the elementary school. The middle school science program should complement and continue the intellectual growth of each child by nurturing these processes. Several factors need to be considered in designing facilities to make the instruction most effective. These include:

- wide variations in student maturity
- the nature of science
- new ideas in science teaching
- the safety of students

SCIENCE ACTIVITIES

Grade 6. Middle school organization of Grade 6 may call for dual-purpose rooms for block classes or a completely departmentalized situation. Usually, the activities at this level will be the same no matter how the room is assigned. However, many science activities require more than normal space allocations. Water, heat sources, and electricity are needed. Some of the activities involve:

- making, using, and displaying weather instruments
- growing plants and animals
- making slides and using microscopes
- measuring, classifying
- interpreting data
- heating liquids and solids
- making maps and charts

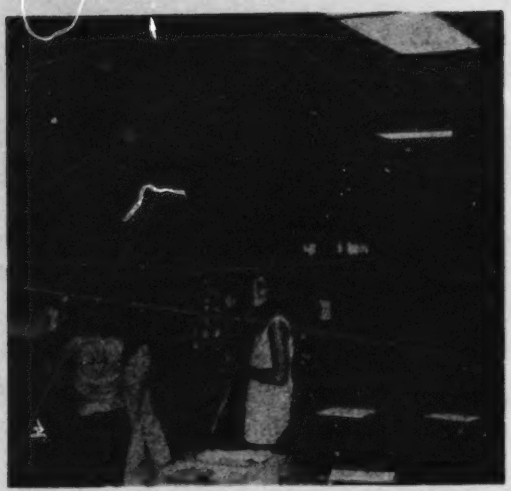


Figure III.1. Operable wall in sixth grade room in a middle school allows for team teaching and for tables to be arranged for group work.

Grade 7. The study of life processes and of the relationships of living things to each other and to their environment forms the basis of the course.

Because a laboratory program is required by the State Board of Education for students in Grade 7, investigations should be designed so that inquiry methods can be used. These investigations should precede and encourage discussion rather than follow conceptual teaching for confirmation purposes only. Typical activities include:

- growing plants and raising animals for observation of growth patterns, energy requirements, reproduction and genetics studies, nutrition studies, and environmental relationships
- using microscopes
- maintaining aquaria and terraria for environmental studies
- investigating diffusion and osmosis and their relationships to life processes

Water, gas, and electricity are needed to carry out the investigations. Students need flat surfaces for group work in various studies and services units for those investigations involving life processes.

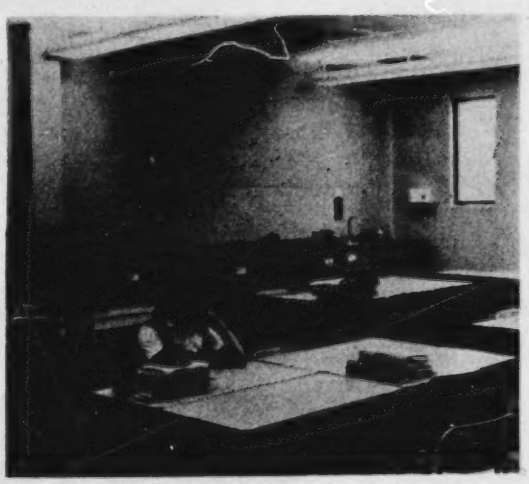


Figure III. 2. A middle school science learning facility has wall service units and individual student tables for flexible grouping.

Grade 8. The required laboratory program for Earth Science includes investigations in geology, oceanography, meteorology, and astroscience.

Because of the scope of the Earth Science course, there is great variety in the activities performed. These include:

- the study of planetary motion and stellar bodies
- weather map and weather instrument construction and use
- studies of density and turbidity currents
- temperature studies
- sedimentation experiments
- mineral and rock character study and identification
- topographic and geologic map construction and reading
- earth history diorama and time line construction

These activities indicate the need for adequate working space and utility installations. Table tops must be large enough to allow students to set up equipment, and storage must be adequate to keep materials for several classes.

Figure III.3. Two-student tables with wall service units allow flexibility in grouping for science instruction.

GENERAL REQUIREMENTS FOR LABORATORIES IN MIDDLE SCHOOL

Although activities vary from one area of middle school science to another, there is enough similarity that a single type of facility can be designed that is appropriate for all needs.

Numerous schools are using a multidisciplinary approach to middle school instruction. Such an approach requires team planning, coordination, and a high degree of flexibility of facilities. A multidisciplinary approach is facilitated by movable partitions that can make space for large groups, a team planning area, media storage, and small-group instruction areas. The curriculum organization should dictate the types of facilities to be constructed.

A science laboratory-classroom in the middle school should contain at least 45 square feet of space per child, and there should be an additional 15 square feet of space per child for storage and materials preparations. Each room should have adequate utilities, gas, water, and electricity with a control valve at each gas and water outlet. Plumbing should be corrosion resistant, and lighting should be adequate for microscope illumination. A clock with a sweep secondhand is a necessity in each science classroom.

All science classrooms should contain a fire extinguisher. (See Laboratory Safety Checklist, page 31.)

Figure III.4. Folding partitions between science classrooms allow flexibility in scheduling large- and small-group instruction.

SUPPORT AREAS FOR MIDDLE SCHOOLS

Stockroom. All stockrooms should have two lockable exits and should be ventilated. To prevent corrosion, chemicals should be stored in a separate stockroom away from other equipment items. Chemical stockrooms should have forced and continuous ventilation. Each stockroom should include laboratory carts properly designed for transporting equipment.

Storage cabinets or shelving should be of at least two widths: narrow for small items and wide for large items. Stacking storage bins for small items makes more efficient use of space.

Preparation Area. Each department should have one or more rooms for the purpose of setting up, testing, and repairing apparatus before its use in the classroom. The preparation area can be part of an equipment storeroom if it has a work surface and utility outlet.

A preparation area should contain lockable doors. It should have a sink with a wall pegboard for drying glassware. A refrigerator is needed for storage of specimens, cultures, and special materials as well as for making and storing ice. An explosion-proof refrigerator is required if it is used for storage of chemicals.

Master controls of utilities for the classroom areas and laboratory should be located appropriately. A work surface with available electricity and hand tools is needed for preparing equipment. The preparation of culture media necessitates a hot plate, free-standing or table top range, and a gas jet for using a gas burner.

Project Room. It is desirable for a school to have a special area where students can conduct experiments or projects in addition to the regular class work. This room should have lockers and table space for individual projects.

Figure III.5. A combination preparation and storage room allows for convenience in setting up student activities.

Nature Areas. Each middle school should have an area of the school campus designated as a nature area that has both natural vegetation and animal life.

Ecological studies of a nature area could include mapping and identifying plant and animal life, seasonal changes in foliation, reproduction conditions, and succession of plants and animals over a period of time. Such studies demand accurate and detailed record keeping and prove to be a very successful life science study.

Junior High School Science Facilities

RATIONALE

All young people have a natural curiosity about the world in which they live, and most educators agree each child has a natural desire to learn. If given the opportunity, children will ask questions and seek answers.

Freedom for inquiry, so stimulating to young people's imagination and ability to learn, is an essential ingredient of a modern science classroom. When the student is allowed this freedom, motivation is high and learning is a natural result. Children who develop skill in the discovery process also develop a motivation to learn and an awareness of their surroundings that will make them more effective in all areas of their educational experiences.

Processes learned in elementary school and in middle school are used as a framework within which to develop concepts in the areas of life, earth, and physical science. The content of these courses is structured to lay a foundation in basic sciences in an atmosphere of enjoyment and success.

ACTIVITIES

Routine classroom procedure begins with a pre-laboratory discussion of investigative approaches to problems. After the laboratory activity is a class or group period of interpretation of data. All courses are laboratory-oriented with a minimum of 40 percent of instructional time devoted to student activities performed individually or in groups of two to four.

Life Science. Life Science is a laboratory-oriented course aimed at building a mature understanding of plants and animals in relationship to their environments. Typical activities include:

- setting up and studying ecosystems
- studying behavior patterns in animals
- manipulating growth factors in plants and animals
- conducting tests and experiments involving conservation and pollution control
- collecting data on pest control
- examining effects of drugs, alcohol, and other mood modifiers on living things
- making population studies
- conducting microstudies of organisms affecting human environment
- studying life cycles

Earth Science. Earth Science is a laboratory-oriented course organized from four areas: geology, astroscience, oceanography, and meteorology. Typical activities involve:

- collecting and collating rocks and minerals
- performing tests to set up classification systems
- constructing models to test phenomena
- constructing and using simple astronomical equipment
- reproducing models of geological formations
- testing materials for erosion
- recording and interpreting weather data
- studying effects of wind and water currents on land formations
- experimenting with temperature and pressure to explain natural forces
- interpreting geological formations

Physical Science. Physical Science is a laboratory-oriented course presenting investigations of physical phenomena designed to develop an understanding of some of the basic concepts of physics and chemistry. Laboratory work stresses the generation of data and their interpretation. The techniques are designed to broaden the students' understanding of the physical world. Typical activities include:

- determining relationships of volume and mass
- manipulating temperature and pressure
- studying force and motion
- classifying materials
- interpreting electrical phenomena
- constructing models to explain observed data
- measuring energy transfers
- investigating the particle nature of matter
- designing experiments to test models

FACILITIES

Although the range of activities varies within a junior high program, a single type of facility can meet all needs. Science rooms must be so organized and equipped that laboratory activities can

be undertaken by students working individually or in small groups (two or four students) as a routine daily procedure.

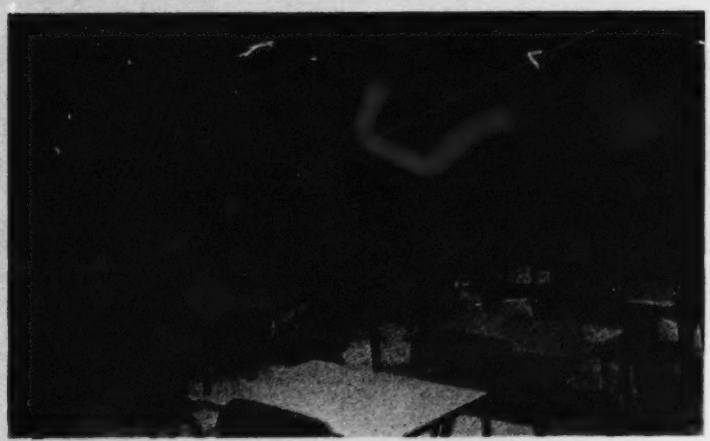


Figure II.1. A junior high science room features perimeter utility services, one alternative arrangement.

Minimums for the Junior High Science Area

The minimum requirements for a junior high science area are:

- 60 square feet of floor space per student, including supportive areas
- tables to permit individual or small-group activities
- wall or island service unit per four students (containing sink, running water, electrical service)
- six duplex electrical outlets properly spaced
- master controls for utilities, immediately available
- ventilated storage for chemicals
- provision for use of audiovisual materials
- storage and preparation area that is accessible from the classroom
- safety items (see Laboratory Safety Checklist, page 31)
- book shelves for references and periodicals

Desirable Items

The following should be added to the basic facilities by planners desiring a more than minimally effective science environment:

Life Science

- refrigerator (see Laboratory Safety Checklist, page 31)

- plant growth center
- animal cages
- vivarium
- aquarium
- terraria

Earth Science

- access to a planetarium
- lapidary equipment
- telescope and related equipment
- photography equipment

Physical Science

- chemical-proof work surfaces

All Laboratories

- shop area with hand tools
- project room for extended studies
- operable partitions between rooms to facilitate large-group instruction

Figure II.2. Wall service units and movable two-student tables give maximum use of space.

Figure II.3. A combined storage-preparation area services several laboratories. (See Figure VII.1. for floor plan of this facility.)

High School
Science Programs and Facilities

A laboratory course is defined as one in which a minimum of 40 percent of the instructional time is allotted to laboratory investigation by students. This does not include time devoted to student or teacher demonstrations. Therefore, by their nature, science classrooms must be furnished to facilitate a laboratory approach to instruction.

Science educators agree that the enrollment in science classes be limited to a maximum of 30 students in any one class. This is not to be an average enrollment but a maximum. However, for safety reasons, it is recommended that not more than 24 students be enrolled in a science class.

GENERAL REQUIREMENTS FOR HIGH SCHOOL LABORATORIES

Minimal facilities for high school laboratories include:

- one sink with water tap, heat source, and duplex electrical outlet for every four students (see Chemistry, page 22 for exceptions)
- five square feet of horizontal work surface per student
- adequate ventilation to facilitate removal of noxious gases
- adequate lighting for good vision and for use of microscopes
- CO^2 or dry-powder type fire extinguisher in every science classroom (see TEA Publication CU0 841 02, *Safety Practices For Science*
- clock with a sweep secondhand in each science classroom

Desirable features that would enhance flexibility of facilities are:

- movable partitions between classrooms to allow team teaching and flexible use of classroom space
- perimeter or island utility outlets complemented with movable two-student tables

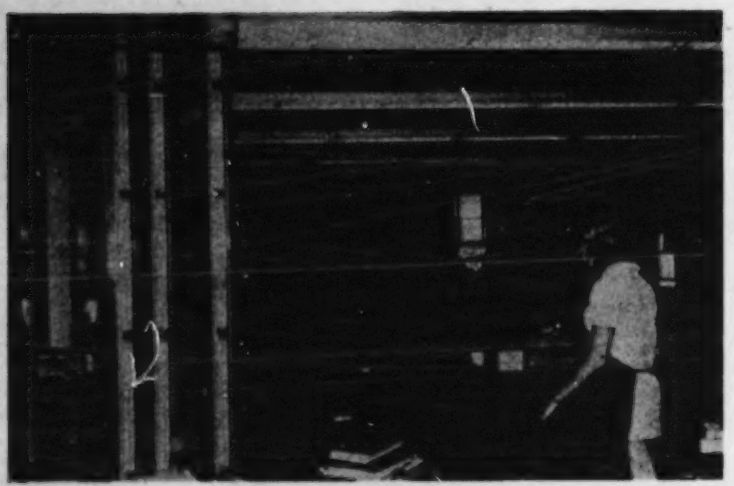


Figure IV.1. An operable wall with mounted chalkboard and a rolling table allows team teaching in adjoining chemistry classrooms.

Senior high school science classrooms and support areas should provide a minimum of 60 square feet of floor space for each student. This allows a safe classroom, encourages laboratory activity, and provides adequate space for storing and preparing laboratory apparatus.

In the planning of air-conditioned science facilities, designers are cautioned to exhaust air directly to the outside from chemistry classrooms to prevent fumes from entering other classrooms and from deteriorating delicate air conditioning equipment in a recycling process. Ideally, a chemistry laboratory should have its own separate unit as a safety precaution. Other classes that use chemicals should be treated similarly.

ACTIVITIES

Physical Science. (See Physical Science, page 15.)

Biology. The laboratory approach is essential if students are to understand life processes and how they apply in their lives. Inquiry activities incorporate a laboratory situation to introduce a phenomenon and a post-laboratory discussion to make clear the concept or principle involved.

Typical laboratory activities in biology include:

- growing plants and animals
- maintaining aquaria and terraria
- making models
- dissecting plants and animals

Figure IV.2. Wall service units at stand-up height, wall cabinets, and two-student tables with chairs make a highly flexible learning facility.

- determining energy content of various food substances
- duplicating biochemical reactions
- observing behavior of organisms
- making culture medium
- culturing organisms
- making and staining microscope slides
- using microscopes

Wall service units can be used effectively for many of the laboratory activities. They should contain sinks, water, gas, and electricity and should have chemical-resistant tops. Individual or two-student tables satisfactorily complement the wall service units. A book rack on the chair is more satisfactory than a book box in the table.

A germinating bed is a valuable instructional device. Light control over the bed is necessary. Where a table is included for holding aquaria and terraria, adequate electrical service is needed for air pumps and lights.

Figure IV.3. A peninsular table arrangement has ample storage area.

Chemistry. Chemistry involves the study of the composition and behavior of matter. Laboratory investigations are concerned with changes that take place in matter and factors causing these changes.

Typical activities in chemistry include:

- measuring masses of substances before and after interactions
- generating, collecting, and testing gases
- growing crystals
- measuring volumes of liquids, gases, and solids
- distilling liquids
- heating and cooling substances
- using burets, pipettes, and other measuring instruments

Laboratory furniture for chemistry should include fume hoods for exhausting noxious gases, laboratory tables with chemical-resistant tops, and cabinet storage space for glassware and common usage items. Special consideration should be given to a floor covering that is chemical resistant. Sinks and plumbing should be made of noncorrosive materials.

Safety equipment should include fire extinguishers, fire blanket, goggles, eye wash, and showers. (See Laboratory Safety Checklist on page 31.) Special utility needs for chemistry for each two students are:

- one water faucet

- one duplex electrical outlet
- one gas jet

Physics. The teaching of physics is changing with additional emphasis being given to laboratory investigations. Adequate space, facilities, and equipment are needed to implement this emphasis.

Typical investigations in physics include:

- motion studies of falling objects, constant velocity objects, and colliding objects using photographs
- optical studies using light rays over a long distance
- nuclear experiments to determine characteristics of the atom
- wave phenomena through the use of ripple tanks and other devices
- energy measurements

Since these experiments are performed by students working individually or in pairs, large amounts of table space are needed. Stand-up height wall service units are usually quite satisfactory for physics labs. Gas and alternating current electrical outlets should be provided for each pair of students. Sinks and water taps are a necessity. The service units are complemented by tables without book box and chairs with book racks.

Portable direct current sources, protected by circuit breakers, are recommended. Built-in central direct current installations usually cause problems of maintenance and are very expensive.

Figure IV.4. Wall service units may take many shapes and allow for instruction in any area of science.

SUPPORT FACILITIES

Stockrooms for all areas should have the following common characteristics:

- locks on all entrances
- separate storage for chemicals with continuous, forced ventilation
- adequate ventilation in all other support areas
- special no-flash containers for flammable chemicals
- carts with raised edges for moving equipment
- shelving with varied depths, or adjustable shelving
- doors into all adjacent classrooms
- entry without going through classrooms
- cabinets for storing large items
- storage for audiovisual materials
- drawers, bins, or boxes for storing small items

Preparation rooms furnish areas for teachers to set up and try out equipment preliminary to its use in the classroom and to repair and service equipment. Provisions to consider in planning preparation rooms include:

- services (gas, water, electricity) as in classrooms
- refrigerator for storing perishable items
- autoclave or dishwasher for sterilizing glassware
- a cooking unit for preparing culture medium
- sink with hot water for cleaning labware
- accessibility without going through classrooms
- master cutoff valves for all classroom utility services
- lockable doors
- work surface with electricity available
- distillation or demineralizing equipment
- adequate ventilation
- cabinets and shelving for storing special items

Figure IV.5. The storage area should be spacious and ventilated and should contain shelving of various heights.

Figure IV.6. Chemicals should be kept in a separate storage area with continuous, forced ventilation. All entrances should have locks.

Figure IV.7. The preparation area should contain a sink with hot and cold water and a drying rack for glassware.

A project room for special student work should contain:

- work surfaces with electricity available
- a sink with hot and cold water
- cabinets for storing incomplete projects
- surface for aquaria and animal cages
- shelving for equipment

SUPPORT AREAS FOR BIOLOGY

The biological sciences can be well served by the inclusion of special facilities such as greenhouses, vivaria, animal centers, and outdoor nature areas.

Greenhouses can provide plants for study and research. They can be purchased or built, using wooden frames with polyethylene covering. An effective greer house requires contolled light, humidity, temperature, insects, and water.

The vivarium is a combination of terrarium and aquarium and incorporates the best features of both. It can be used as a greenhouse or animal cage and is highly effective for providing an observation center for students.

An animal center should be well ventilated and should have humidity and temperature controls, floor drains, faucet connections, and wall surfaces that can be easily cleaned. Tables or counters are provided for animal cages. Storage areas for food and a sink for cleaning utensils and feeding trays are necessary.

Figure IV.8. Many forward-looking schools are designating areas to be left in their original states for ecological and population studies.

Outdoor nature areas can be most useful and convenient if they are part of the school campus. Ideally, they should contain a variety of environments—grasslands, trees, aquatic, and desert

areas. However, any nature area can be a valuable asset if used properly for student observation, recording, and experimentation. Every school campus should have a designated nature area that is left untouched.

Access to a planetarium can enrich the experiences of students, especially at the middle, junior high, and high school levels. Generally, satisfactory utilization of such a facility can be realized only if the school district owns the installation.

Figure IV.9. Twin rear projection screens add flexibility to the types of programs available for presentation in a planetarium.

An Audio-Tutorial* Approach To Learning

For school administrators who wish to implement independent science instruction, the following is presented as one approach.

Figure V.1. Students differ in their responsiveness to different kinds of communication devices. Some can learn best by handling specimens and performing experiments. Some can use this and supplement it greatly by reading. Numerous authorities feel that many students benefit the most by this latter combination of using multimedia instruction through a multifaceted, multisensory approach to learning.

Figure V.2. In the supervised independent learning center, students check in for as long as they need or desire. If they have additional questions, they can get immediate assistance from the instructor on duty without slowing down the remainder of the class.

*_An Audio-Tutorial Approach to Learning_ (Minneapolis: Audio-Tutorial Systems, a division of Burgess Publishing Company, 1969). Photographs reproduced by permission of the publisher and of Dr. S.N. Postlethwait, developer of the audio-tutorial program at Purdue University.

Figure V.3. Direct and meaningful personal contact between teacher and student happens informally and frequently using audio-tutorial methods.

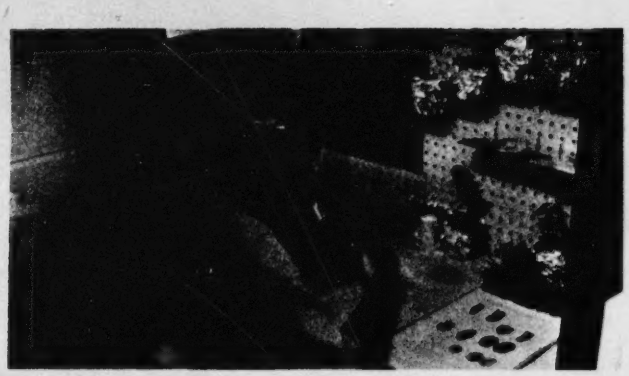


Figure V.4. Each student progresses at his or her own rate.

When the learning objectives of the course are correlated with the capabilities of an audio-tutorial system, advantages can be derived.

To students it provides:

- learning experiences presented in logical, integrated sequence
- the opportunity to proceed at their own paces and to achieve a better understanding regardless of their backgrounds, aptitudes, interests
- a closer teacher-student relationship
- the responsibility for their own rate of progress
- relevant, timely material with high interest value

To the teacher it offers:

- a rewarding experience since all levels of students may learn the limits of their abilities
- the time to provide the guidance, orientation, and personal contact necessary to inspire and motivate students to greater effort
- a chance to use a variety of materials in teaching presentations more effectively
- the freedom for more effective personal contact with students—the freedom from rote presentation

To the administrator it means:

- modern teaching techniques are provided to meet the need for change caused by today's knowledge explosion
- significantly more students may be accommodated in the same area

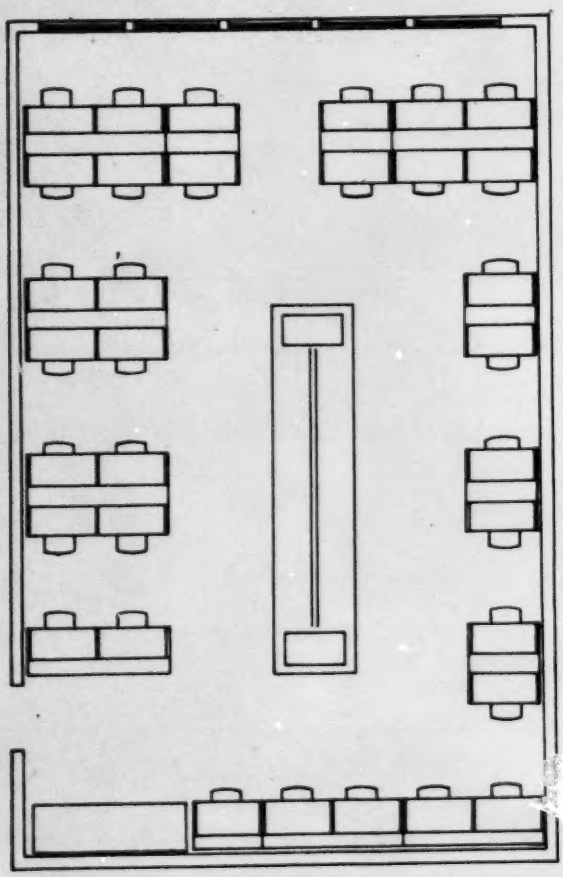


Figure V.8. Audio-tutorial learning center has experimentation and supply area in center of room.

Safety In The Laboratory*

LABORATORY SAFETY CHECKLIST

	Eye Protection (1)	Fire Extinguisher (2)	Fire Blanket	Utilities Master Control	Eye Wash (3)	Shower (4)	Aprons	Explosion-Proof Refrigerator	First-Aid Kit
Life Science	x	x	x	x	x		x	x	x
Earth Science	x	x	x	x	x		x	See (5)	x
Physical Science	x	x	x	x	x	x	x		x
Biology	x	x	x	x	x		x	x	x
Chemistry	x	x	x	x	x	x	x	x	x
Physics	x	x	x	x	x		x		x

(1) Can be goggles or shields (see Appendix, pages 54-55.)

(2) Must be CO_2 or dry powder estinguisher

(3) Can be hand operated (see Figures VI. 1, VI. 2., and VI. 3.)

(4) Can be hand operated (see Figures VI. 3., and VI. 4.)

(5) If refrigerator is used to store flammable chemicals, it *must* be explosion proof. A standard refrigerator can be made explosion proof by removing all internal electrical switches and by placing cooling unit on top.

*See ***Safety Practices for Science,*** TEA Publication CU0 841 02, for detailed instruction on safety.

Figure VI.1. Hand-operated eye wash is portable.

Figure VI.2. Stationary type eye wash has dual spigots.

Figure VI.3. Portable apparatus combines shower and eye wash, shown in stored position.

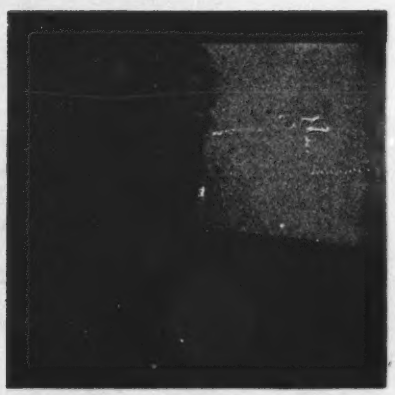


Figure VI.4. Hand-operated shower has flexible hose.

Sample Plans For New Construction

To aid architects and school planners, the following floor plans of learning facilities are presented. They exemplify the guidelines set forth in preceding sections of this publication. The plans incorporate maximum flexibility and allow for instructional efficiency while minimizing construction cost.

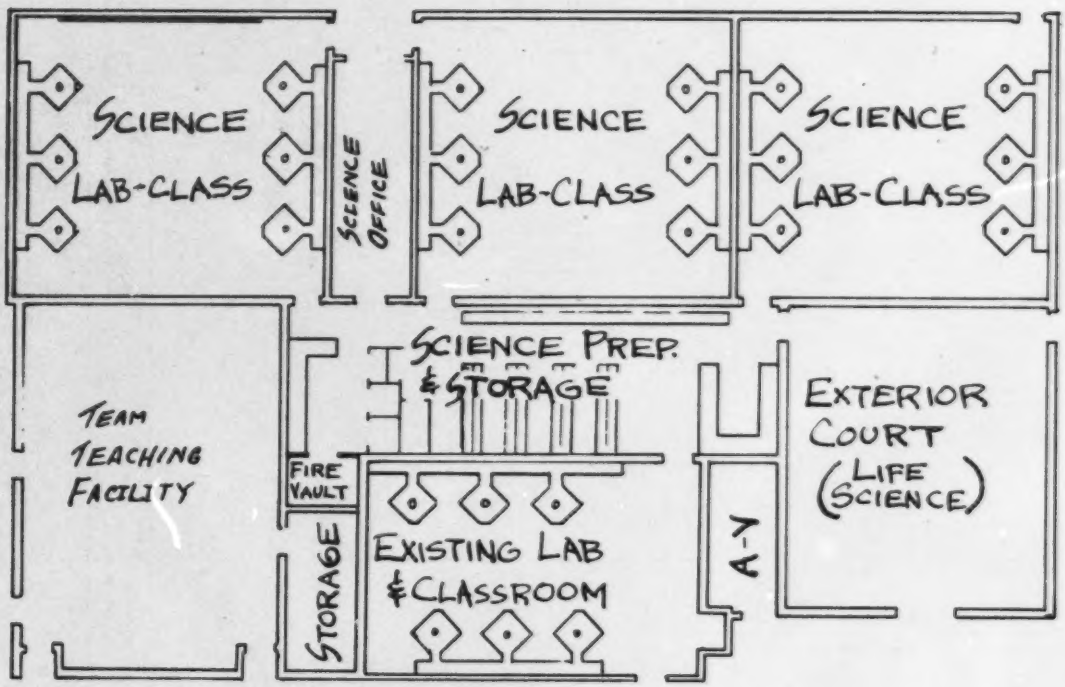


Figure VII.1. Combination lecture-laboratory showing central storage and exterior court for the life sciences.

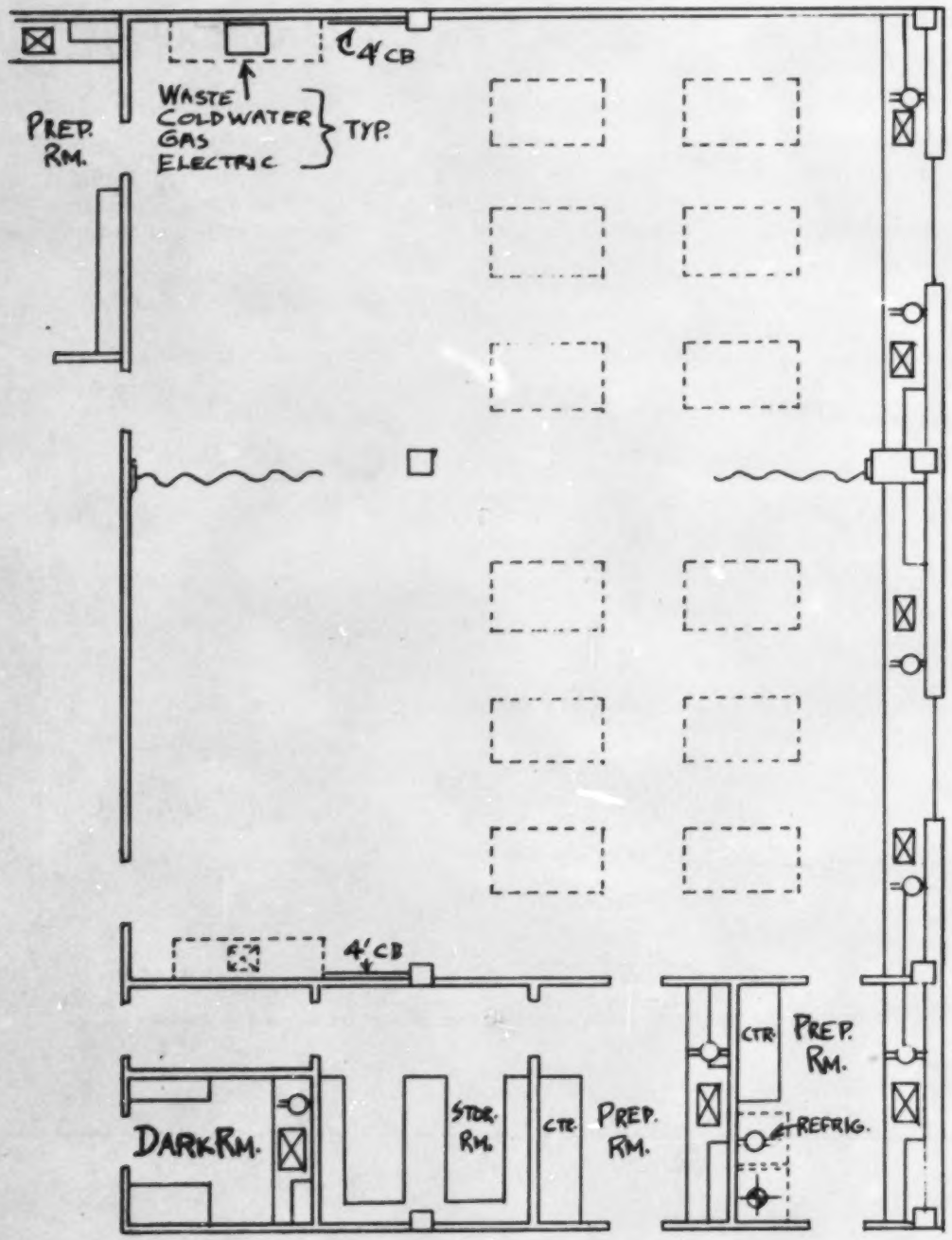


Figure VII.2. A plan showing operable partitions between two science classrooms to encourage team teaching.

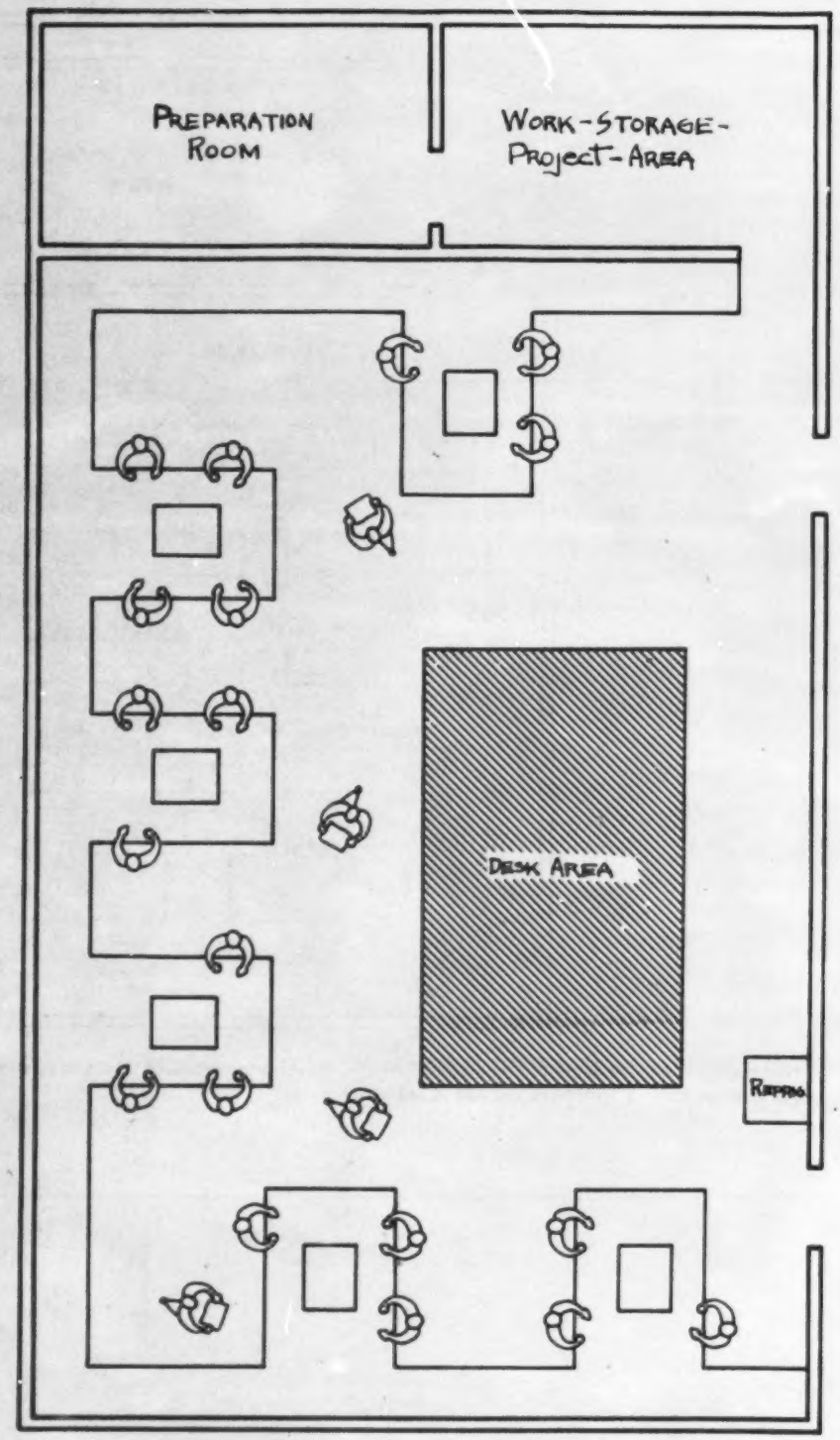


Figure VII.3. Peninsular-type work areas of stand-up height, complemented by desk chairs with book racks.

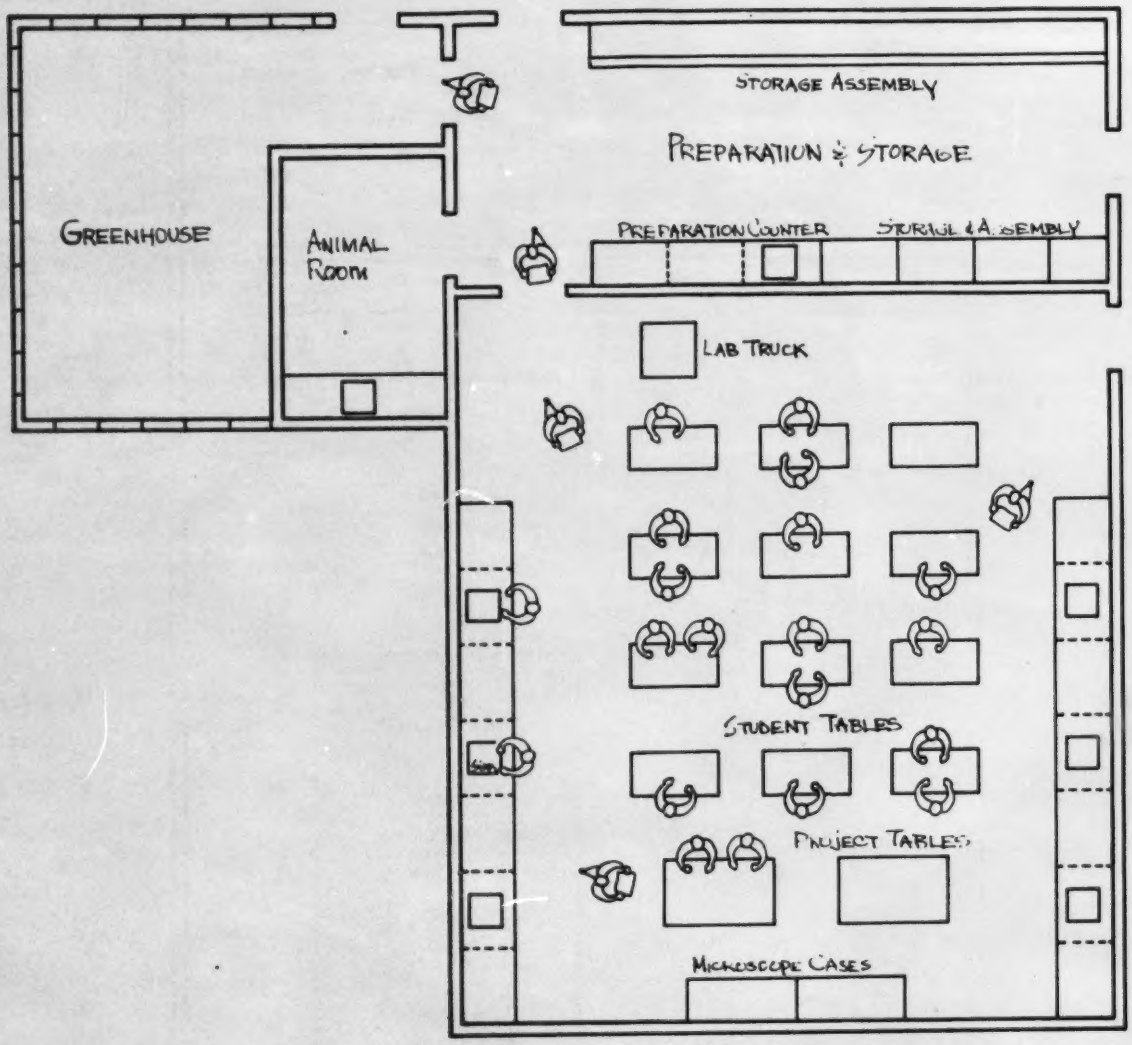


Figure VII.4. Perimeter installation of work units of stand-up height plus movable two-student tables of sit-down height provide flexibility. An animal room and a greenhouse are added features.

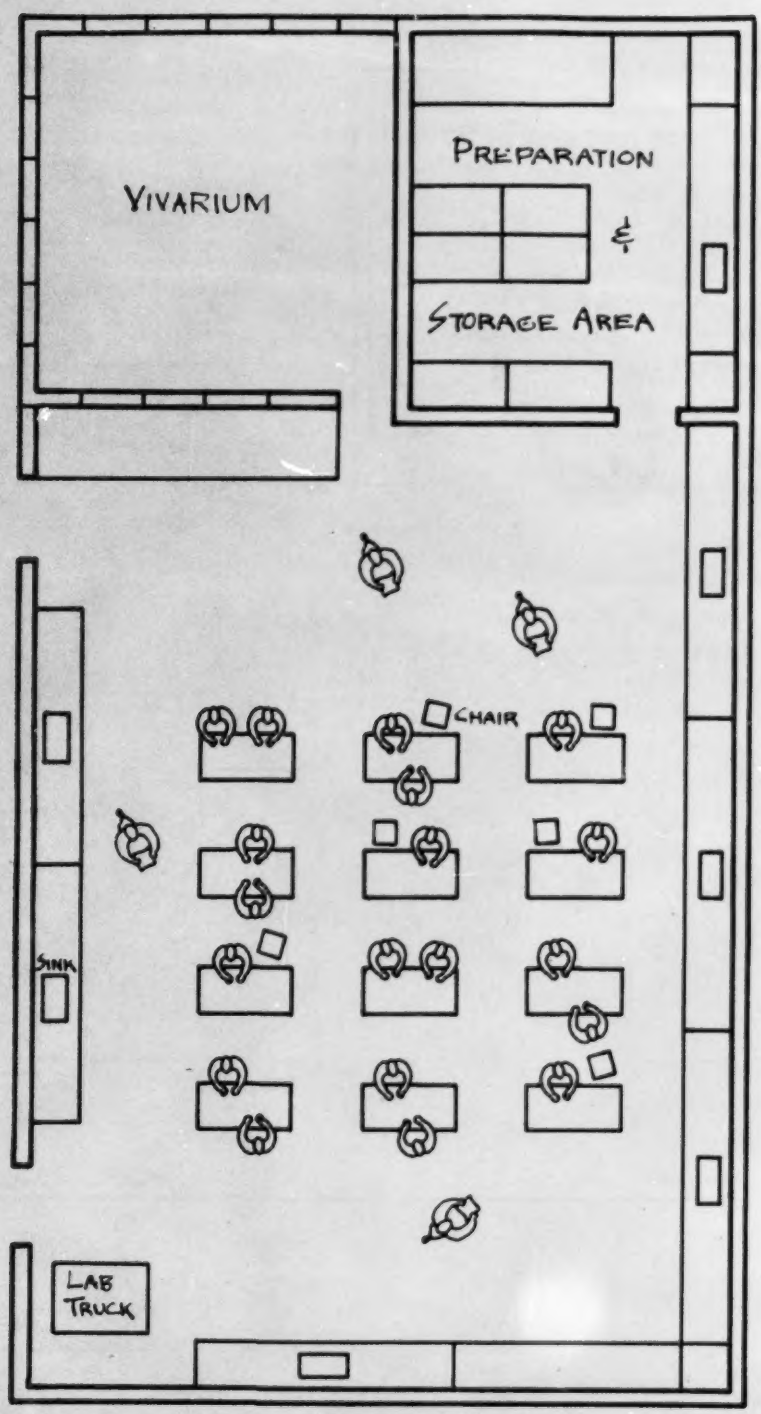


Figure VII.5. Stand-up height installation of utility facilities, complemented by two-student movable tables and a vivarium, provide for flexible arrangement.

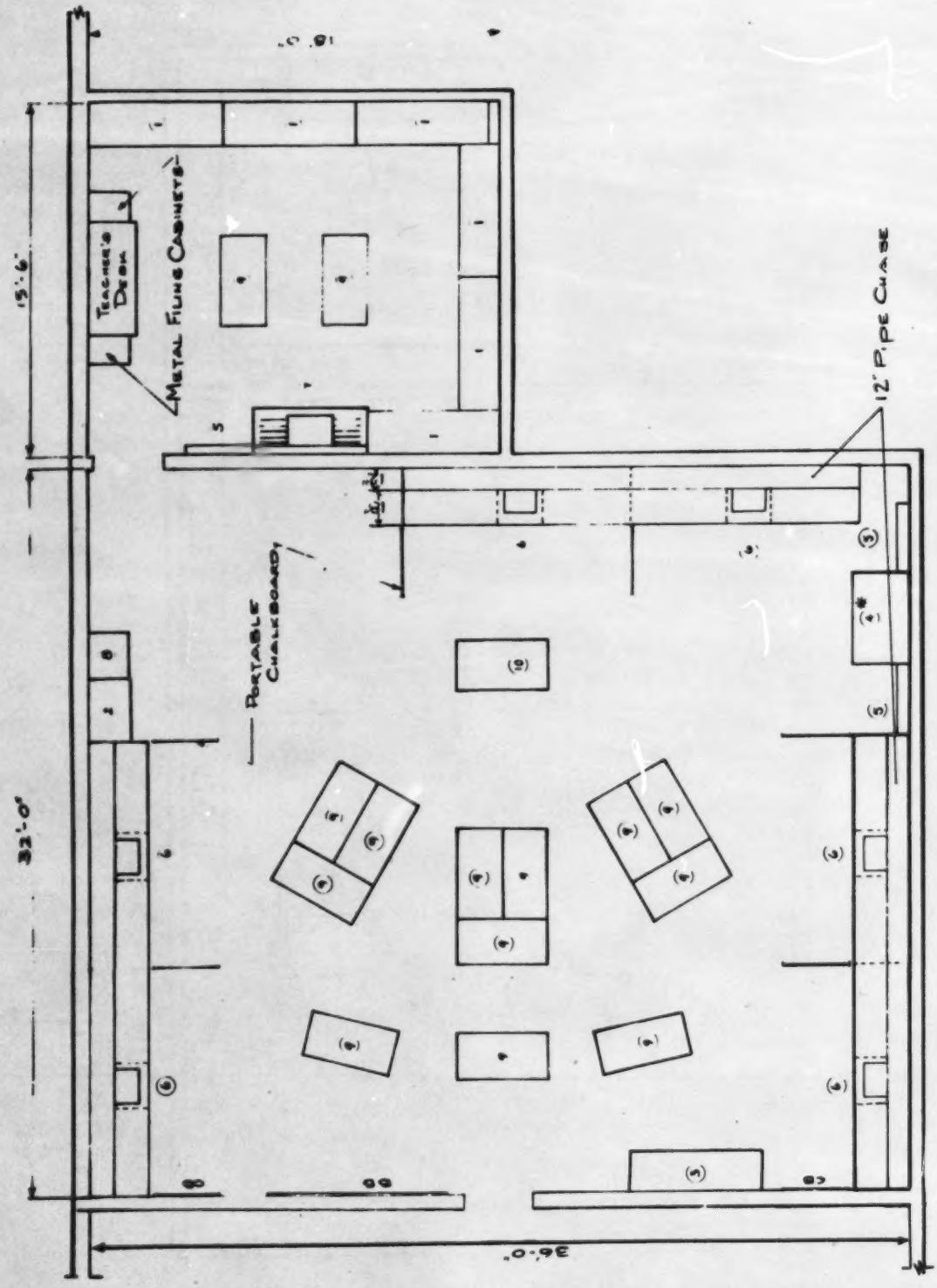


Figure VII.8. Stand-up height installation of utilities and two-student tables at sit-down height provide for instructional flexibility. An elevated pipe chase allows extra storage surface. Numbers are keyed to Figure VII.7.

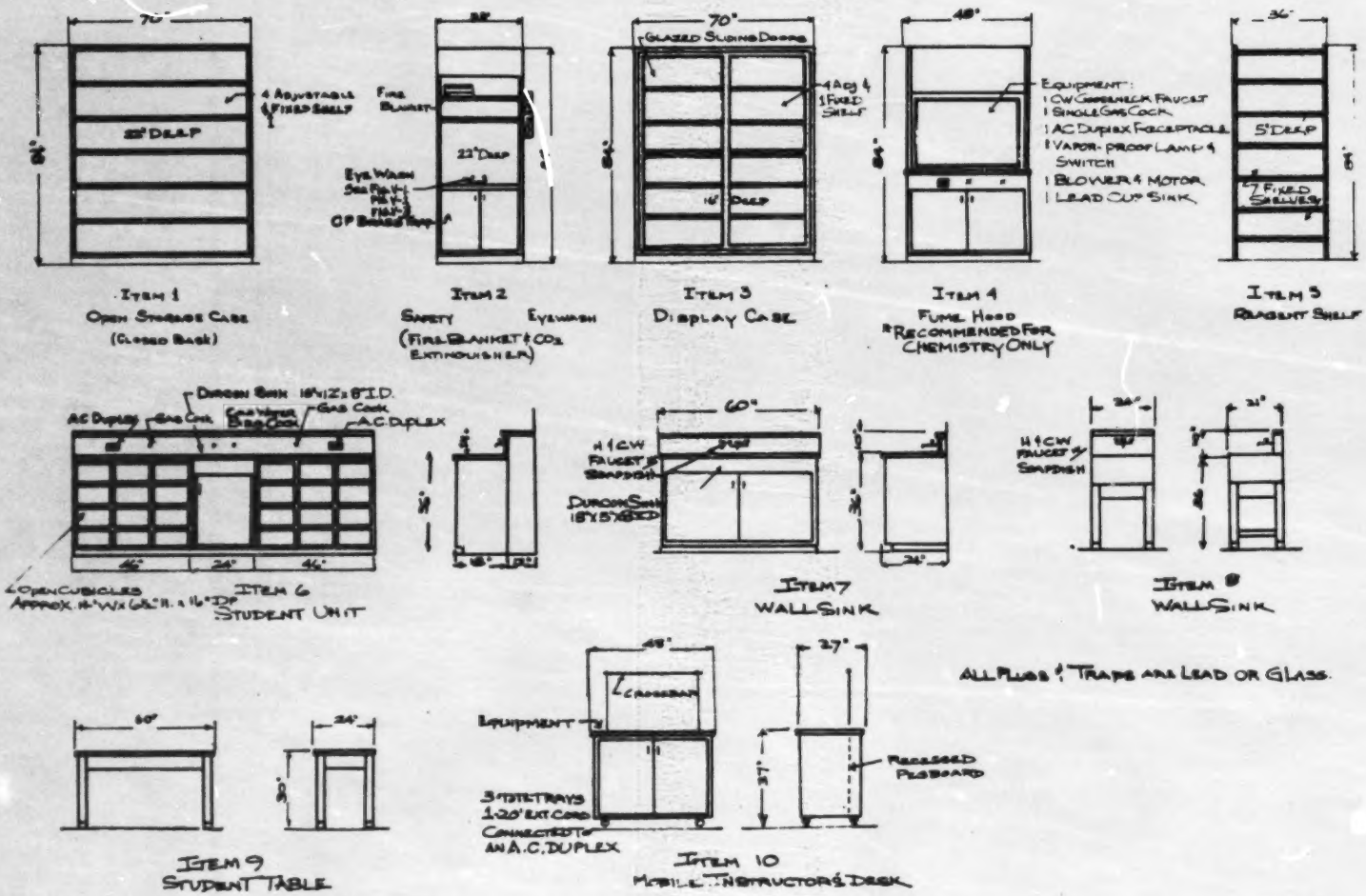


Figure VII.7. Detailed sketch of laboratory furniture shown in Figure VII.6.

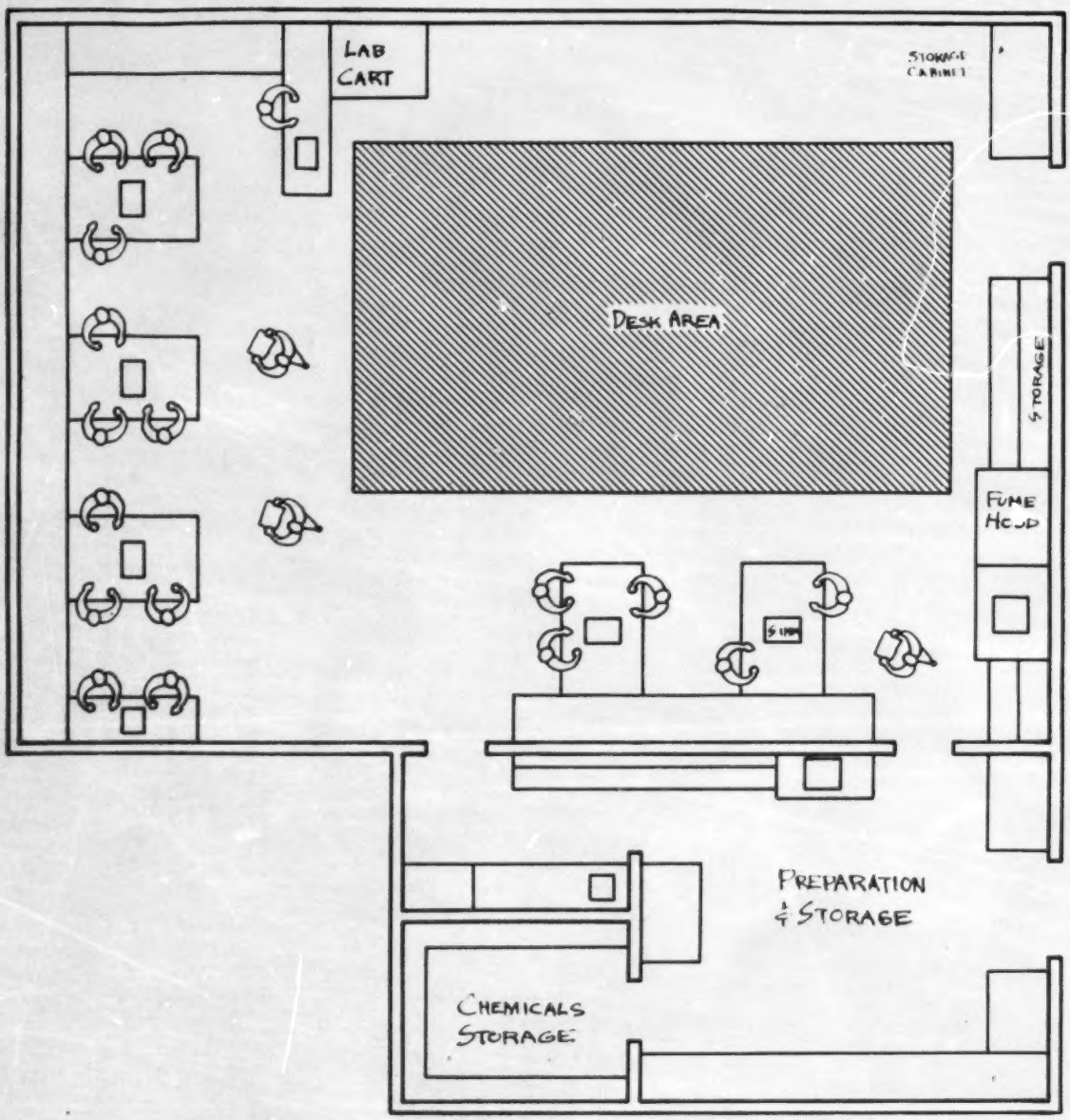


Figure VII.8. A peninsular arrangement of the utility outlets and lab tables, complemented by chair desks with book racks.

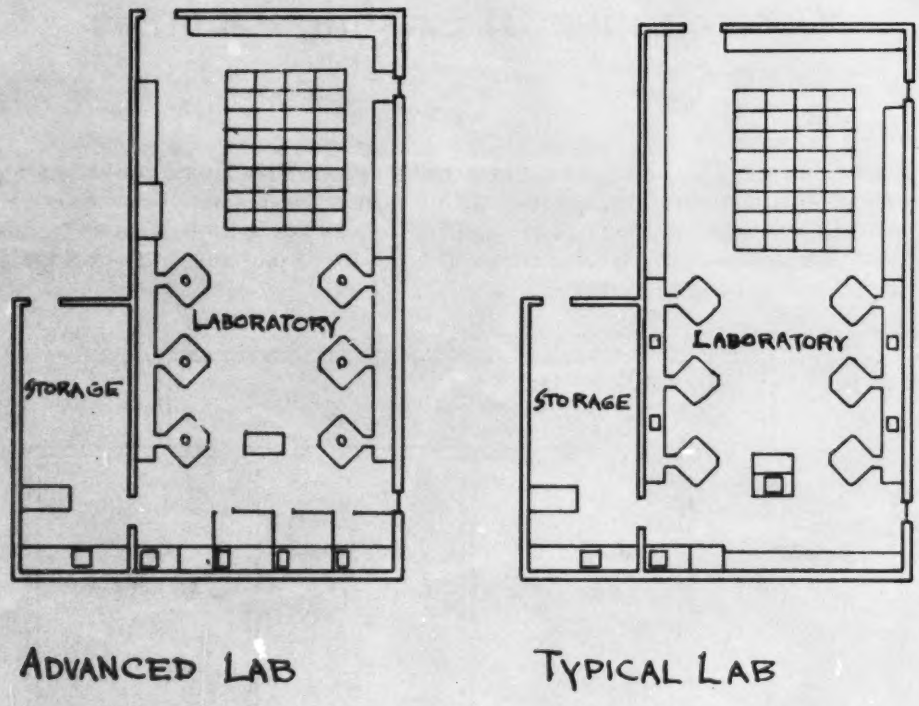


Figure VII.9. Combination classroom-laboratory showing study carrels, laboratory islands, and storage.

In collaborating with planners of new facilities, administrators and science teachers should review and evaluate all possible types of construction. Several research projects involving the use of the systems approach and modular construction show much promise. A report on these projects entitled "Systems" has been produced by Educational Facilities Laboratories, 477 Madison Avenue, New York, NY 10022.

Modernization Of Existing Facilities

Many schools with inadequate science facilities contain space that can be converted into usable science learning environments through remodeling. When making renovations, consideration should be given to provision for adequate storage, use of wall space for service units, flexible furniture arrangement, and availability of utilities. The following pictures and drawings show examples of facilities that have been remodeled.

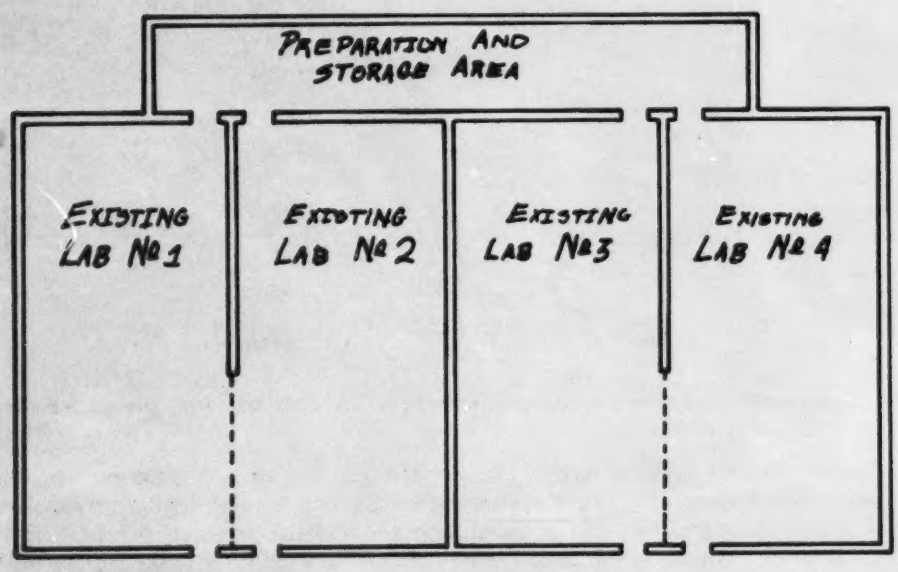


Figure VIII.1. Combination laboratory showing the addition of storage and preparation. (See Figure II.3. for photograph of this facility.)

Figure VIII.2. Peninsular unit was added to existing service unit where neither floor nor walls were available for plumbing and services.

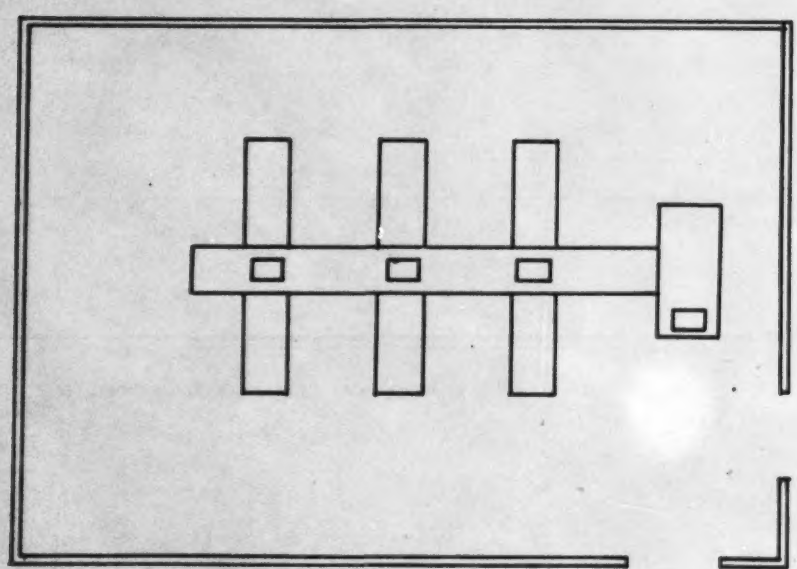


Figure VIII.3. Sketch of facility shown in Figure VIII.2. (storage facilities not shown).

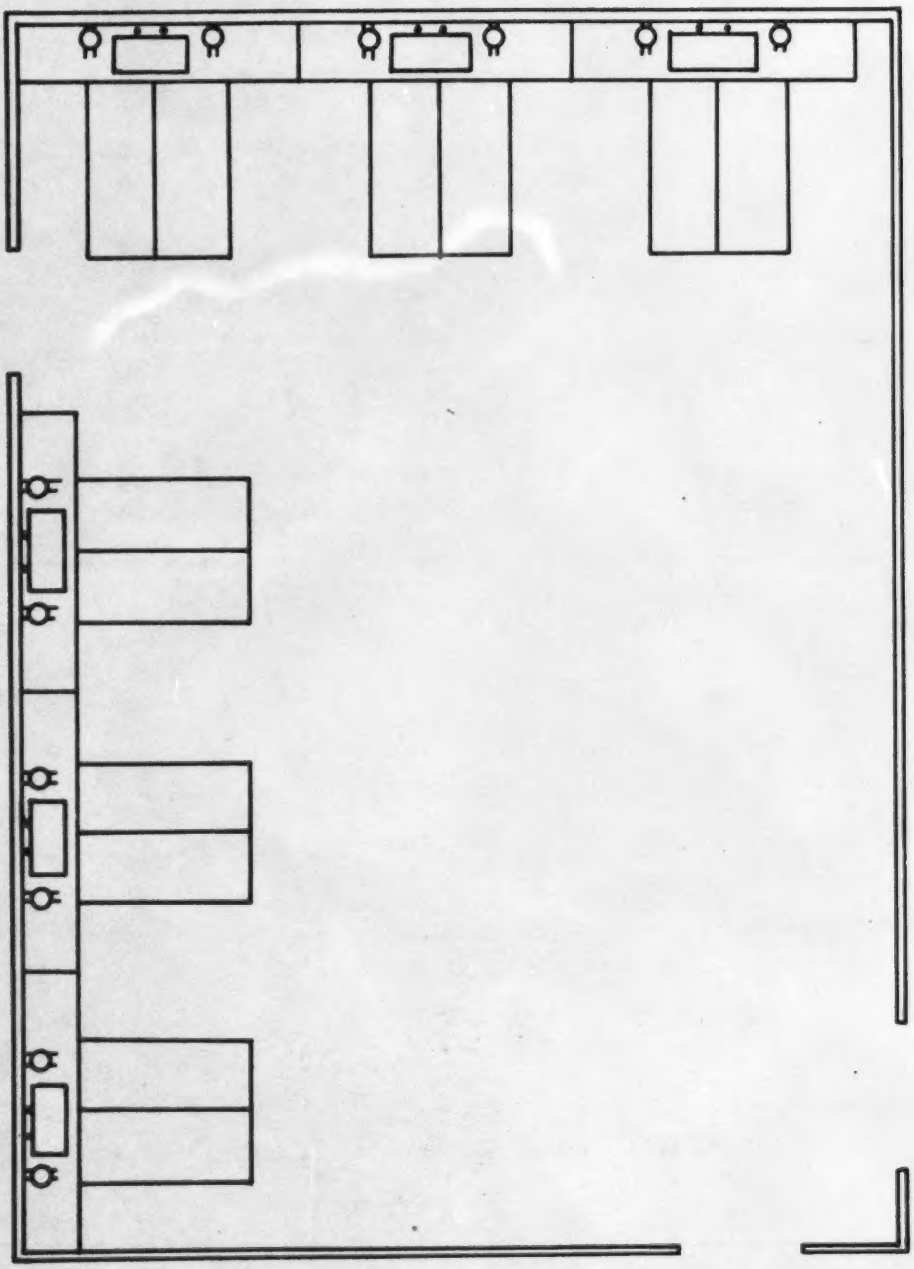


Figure VIII.4. Basic facility of wall service units and movable tables.

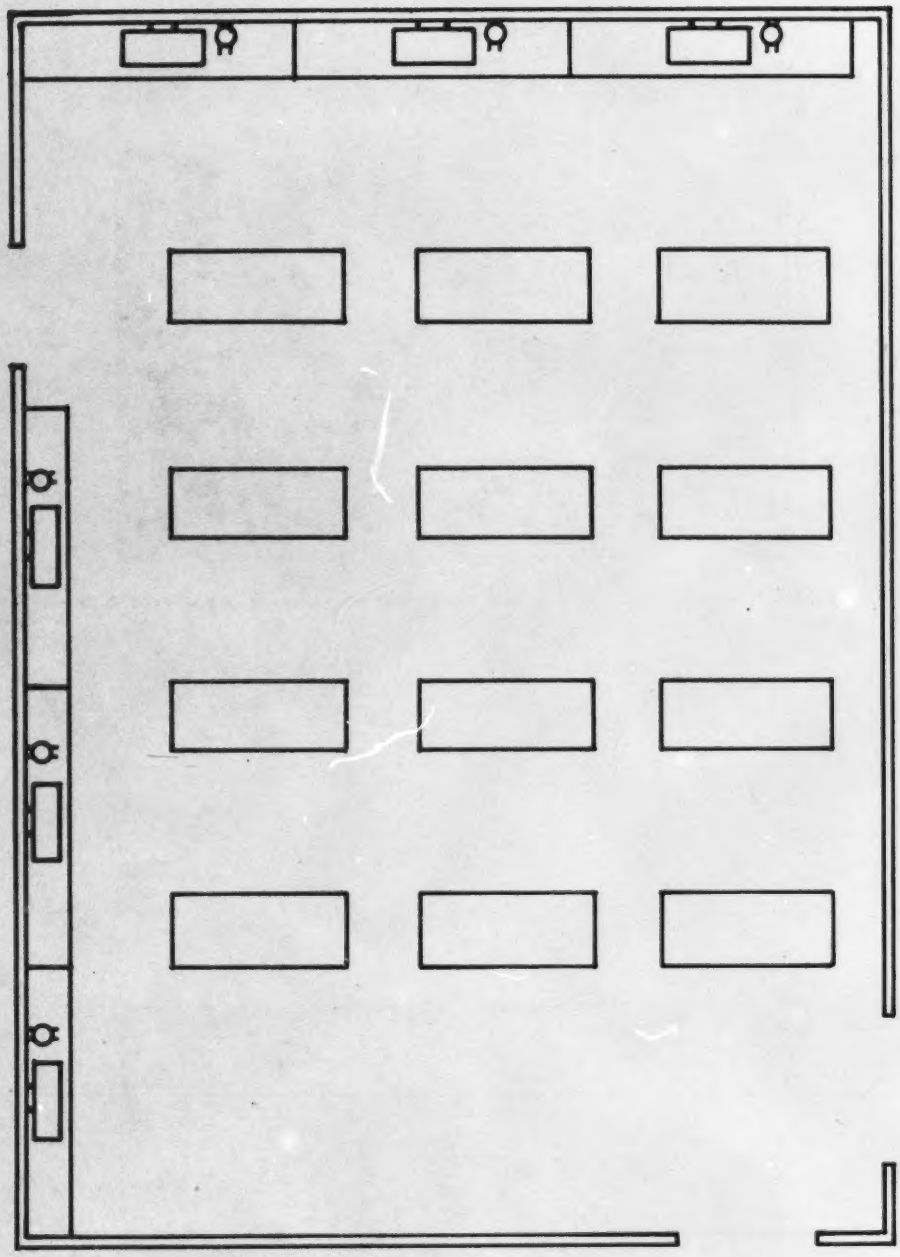


Figure VIII.5. Basic facility with wall service units and movable tables. This is the same facility shown in Figure VIII.4., with two-student tables arranged for discussion session.

Figure VIII.6. Shop-made utility units with work areas decrease the capital expenditure.

Figure VIII.7. Folding tables with gas and electricity and wall cabinets with sinks between each two tables increase clearance space when not used as lab.

Appendix

Conditions of Instructions*

In 1970, the Commission on Professional Standards and Practices of the National Science Teachers Association published its recommendations for conditions for effective instruction for secondary science teachers. The sections dealing with teaching assignments, working space, services, and budget are reprinted with permission.

By conditions of instruction are meant the circumstances under which teachers work. Perhaps the most important of these conditions is the general vigor and health of the learning environment. If there is mutual respect between teachers and students and administrators, if there is a general high regard for learning for its own sake, and if the educational interests of all students are kept paramount, then it is likely that good conditions for learning and teaching will prevail.

The recommendations that follow deal with some of the specifiable aspects of conditions for instruction. They are based on the assumptions that science teachers' total assignments must reflect the complexities of their jobs, that science teachers must be given ample time both for instruction itself and for preparation, and that they need to be provided with ample backup support, such as suitable working spaces, an adequate operating budget, and services of several kinds.

TEACHING ASSIGNMENTS

34. Science teachers should not be asked to be responsible for the education of students in content areas in which they are not competent in subject matter.

> This recommendation should not preclude involvement in developing or teaching interdisciplinary courses, experimentation in new modes of presentation, team teaching, interdepartmental seminars, or other as yet unforeseen innovations.

35. A science teacher should not have more than two preparations or class-management situations.

> Because of recent changes in the organization of science instruction, it is no longer as clear as it once was what constitutes a "preparation." In a sense every single class constitutes a separate preparation. Indeed, as schools move toward individualized instruction, the job of teachers is changing radically, requiring them to think in terms of guiding each of their students as a separate person and diminishing their concern for group instruction. But whether a teacher operates predominantly in the group instruction mode or relies mainly on individualized instruction, there needs to be some reasonable limitation to his or her separate preparation situations.

*Commission on Professional Standards and Practices, National Science Teachers Association, *Conditions for Good Science Teaching* (Washington, D.C.: The Association, 1970), pages 10-13.

36. If science teachers are given assignments of unusual responsibility, their total load should be adjusted to a reasonable level.

Teachers given assignments such as department chairperson, master teacher supervisor of apprentice teachers, or chairperson of a curriculum study group, cannot be expected to carry out effectively and still do full justice to their primary responsibilities of teaching unless some adjustment is made. Of course, the adjustments should be in proportion to the magnitude and intensity of the added assignments.

37. Each science teacher's week should be programmed so that there is some time available to meet with individual students.

Office hours should be posted so that students can consult teachers without difficulty.

38. All laboratory sections should be strictly limited to a maximum of 24 students per instructor.

This restriction is necessary because useful laboratory work—the heart of modern science instruction—requires individual participation by students and close student-teacher liaison. To increase the recommended number of students is to jeopardize the educational value of science experimentation and inquiry. Furthermore, a teacher simply cannot supervise more than 24 students, even in the restricted sense of keeping order. The risk to student safety and to expensive equipment escalates rapidly as the number of students in the laboratory at one time increases. In instances where existing laboratories have fewer than 24 work stations, the number of students assigned should not exceed the number of stations.

39. Group discussion classes should be limited to a maximum of 24 students.

Unlike the laboratory situation, it is not hazardous to students and equipment to have more than 24 students per class, it is educationally unsound to do so. Classroom discussion and activities (instruction in science, even outside the laboratory, involves more than "talk," if it is not to become disguised lecturing) must provoke the participation of all students and not just the most articulate few. This is difficult to achieve under any circumstance, but as the numbers rise it becomes impossible, and quality of instruction suffers.

40. A science teacher's involvement in extracurricular activities should be limited.

All teachers, including science teachers, must join in the responsibility for carrying out the whole school program (providing, of course, that they have had a hand in designing that program), and certainly this involves more than formal instruction. However, activities not directly related to the science program, like all activities, require time and energy, and thus extensive participation in them may seriously detract from teachers' abilities to fulfill their major teaching responsibilities.

Any major nonteaching related assignments accepted by science teachers should be compensated for by reductions in their teaching loads (see Recommendation 46), then in view of science teachers' heavy laboratory responsibilities, they should not be asked to take any extracurricular assignments.

WORKING SPACE

The most obvious and uncontested claim for space in a school is for instructional rooms. Those are the spaces in which teachers and students work together. However, such facilities are not by themselves sufficient. If teachers are to make effective use of their instructional time, they must have available places where they can do the work necessary to prepare for instruction.

41. Ample space is needed for the storage of supplies and equipment.

    This space, equivalent to at least 15 percent of the laboratory space, should be adjacent to the laboratories if at all possible. This is in addition to the storage space provided in each laboratory. Some of the newer classroom buildings have been designed so that the storage space is more or less common to all of the laboratories. Such an arrangement may be satisfactory, provided there is continuous adult management of it and provided also that there is separate, isolated storage for flammable, poisonous, and corrosive substances. If animals are kept permanently at the school, then special animal room must be provided and some arrangement made for year-round humane care of the animals.

42. Every science teacher requires access to a preparation area free from students.

    Teachers need a place where they can prepare materials for student experimental work, set up and test demonstrations, and sometimes conduct experiments of their own. Depending upon the design of the department, these teacher preparation areas may be provided as part of extended storage space or as separate rooms. In either case, the preparation areas must be provided with convenient electric, water, and gas outlets, waste disposal facilities, and safety devices.

43. Every science teacher should have private office space.

    If a teacher has the same classroom all day, and no other teacher uses that room throughout the day, then it may be possible for a teacher to use his or her classroom as an office. However, those conditions do not prevail in most schools, and since teachers need a place where they can do their paper work without interruption and where they can keep files of confidential materials, it is sounder to provide regular office space.

44. The science teacher needs access to a professional library.

    This library should exist as a separate facility within the school. Science teachers, faced with the task of staying up-to-date in a science and its applications, in the teaching of science, and in matters relating science to society, carry a heavy academic burden. Consequently, they need to study appropriate books and journals almost continuously. To accomplish this, they should have immediate access—this is part of their daily work, not something that can be put off until summers—to a professional library that contains appropriate material. They cannot function effectively for long without such a resource any more than can scientists or college science teachers.

SERVICES

In order to do their jobs well, science teachers need considerable assistance of many kinds. No matter how talented teachers may be in the art of instruction, it does not follow that they are particularly competent at typing, filing, cleaning and repairing equipment, and the hundreds of other chores associated with their jobs. Furthermore, it is poor economics, as well as a shortsighted employment policy, to expect teachers to do ineffectually what others can do better and at lower

cost. But it is not only with "chores" that science teachers need help. They can do better jobs of teaching if they receive leadership and help from persons who not only themselves are master teachers but also have extensive knowledge of and deep insight into the major facets of science instruction and curriculum. The following recommendations indicate the kinds of persons needed to provide teacher backup services.

45. Schools employing four or more science teachers should have a science department headed by a chairperson.

The prime function of a department chairperson is the improvement of science instruction. This involves management duties, supervisory functions, curriculum leadership, and seeing that the teachers in the department are given as much help as possible. The science chairperson's teaching load should be adjusted to permit him or her to devote not less than half of each school day to department duties.

46. Laboratory assistants should be available on a professional basis.

The chief tasks of these paid adult assistants would be to assist the teacher with such things as setting up demonstrations and student laboratory experiments, and ordering, assembling, maintaining, and keeping an inventory of supplies and equipment.

47. Professional, secretarial, and clerical help should be available to science teachers on a systematic basis.

Such help should be available at least one hour a day to each teacher at a time convenient to her or him. Student help is no substitute for this.

48. Consultants and specialists should be called in to help the science department and science teachers as needed.

These may be safety engineers, specialists on new science programs, specialists on the utilization of new learning technology, science educators to help individual teachers with classroom problems, and the like.

BUDGET

Each science teacher must be supported directly or indirectly by an adequate budget. Because of differences in local facilities and programs, it is not possible to specify here the exact size of the budget necessary to meet the annual and long-term needs of all high school science departments; thus, it becomes imperative that the budget be arrived at during meaningful consultation with those who understand best the local school science situation, namely, the science teachers themselves. The following recommendations provide some guidelines in the development of an adequate budget.

49. The science department budget should appear as a separate account within the whole school budget, and it should be subdivided functionally.

Separate line items should indicate the amounts budgeted for the purchase of laboratory equipment, for the repair and maintenance of equipment, and for supplies. The intended purpose of this is to eliminate unnecessary confusion over the true size of the science budget, or over the relative distribution within the department between capital outlay and annual operating expenses. Such information is necessary if the science teachers are to plan intelligently.

50. Supplies should be budgeted on a per capita basis with the amount varying according to the nature of the course and the consumable materials involved.

It must also be kept in mind, however, that there exists a bare cost below which any science course cannot operate, no matter how few students are enrolled in it.

51. Budgetary provision needs to be made so that items may be ordered during the school year for new projects, for perishable materials, and for unforeseen contingencies.

To facilitate this, the science department should have a substantial petty cash fund that every teacher in the department can draw upon for purchases of emergency science materials.

52. If a science department does not possess all of the major equipment that the science teachers and department head agree is essential to the department program, then there should be explicit budgetary provision for obtaining all such equipment in no less than three years.

Needless to say, this must be accomplished without unnecessarily reducing the annual operating budget. This recommendation recognizes the fact that major equipment deficiencies usually cannot be made up in a year. A period of three years allows the situation to be rectified in an orderly and manageable way. Decisions on the particular capital items to be purchased and on the order of priorities must be decided by the science teachers, not by school administrators.

Selected Safety Directives

The following are excerpts from state laws and regulations that apply to safety in science education:

- *Texas School Law Bulletin,* Texas Education Agency Publication BU8 013 01, Section 21.909, page 192:

  Sec. 21.909. PROTECTIVE EYE DEVICES IN PUBLIC SCHOOLS.

  (a) Industrial quality eye-protective devices shall be worn by every teacher and pupil in Texas participating in any of the following courses:
    (1) vocational or industrial arts shops or laboratories involving experience with:
      (A) hot molten materials;
      (B) milling, sawing, turning, shaping, cutting, or stamping of any solid materials;
      (C) heat treatment, tempering, or kiln firing of any metal or other materials;
      (D) gas or electric arc welding; or
      (E) caustic or explosive materials; or
    (2) chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids.

  (b) In this section, "industrial quality eye-protective devices" means devices meeting the standards set by the State Department of Health.

  (c) The governing boards and administrators of Texas school districts offering any of the listed courses are responsible for furnishing free of charge or providing at cost to teachers and pupils participating in the courses the required eye-protective devices.

  (d) Whenever an accident occurs during the conduct of any of the courses described in Subsection (a) of this section, and an injury to the eye of a teacher or pupil results, the Principal shall make a full written report of the accident and injury to the State Department of Education. The department shall prescribe the form and content of the reports and shall maintain a file of all reports submitted.

- *Standards for Eye Protection in Public Schools,* Texas State Department of Health, Health Regulation No. 5, Section 5.5, pages 6-7.

  5.5.1 Description. Goggles shall consist of a frame (composed of a flexible, chemical-resistant, nontoxic, nonirritating, and slow-burning material, forming a lens holder), lenses, and a positive means of support on the face such as an adjustable headband of suitable material to retain the frame confortably and snugly in place in front of the eyes. The lens holder shall be such that the lenses are held firmly and tightly and may be removed or replaced without the use of tools. The goggles may be ventilated or not, as required by their intended use. Where chemical goggles are ventilated, the openings shall be such as to render the goggles splashproof.

  5.5.2 Protection. Goggles shall provide eye protection from fine dusts, fumes, liquids, splashes, mists, and spray.

  5.5.3 Application. Specific application for use of flexible fitting goggles will be found in Table I [page 58].

  5.5.4 Materials and Methods of Test. Plastic lenses used in flexible fitting goggles shall be not less than 0.050 inch in thickness. Materials used shall be capable of withstanding the disinfection, corrosion resistance, water absorption, and flammability tests outlined in Section 6.

- *Standards for Eye Protection in Public Schools,* Texas State Department of Health, Health Regulation No. 5, Section 6.2, page 9.

  6.2 Disinfection. All materials shall be such as to withstand, without visible deterioration or discoloration, washing in detergents and warm water, rinsing to remove all traces of detergent, and disinfection by the following methods:

  (1) Immersion for 10 minutes in a solution of formalin made by placing one part of 40 percent formaldehyde solution in 9 parts of water at a room temperature of 68°F.

  (2) Subjection to a moist atmosphere of formaldehyde for a period of 10 minutes at a room temperature of 68°F.

  (3) Immersion for 10 minutes in a solution of modified phenolics, hypochlorite, or quaternary ammonium compounds in strength specified by the manufacturer at a room temperature of 68°F.

- *Standards for Eye Protection in Public Schools,* Texas State Department of Health, Health Regulation No. 5, Table 1, page 12.

TABLE I

Selection of Eye- and Face-Protective Devices

Hazard Involved	Part To Be Protected	Permissible Protective Devices Type
Dust and small flying particles	Eyes, Face	Goggles Spectacles Face Shields
Gases, fumes, and smoke	Eyes, Face	Goggles
Liquids	Eyes, Face	Goggles Face Shields

COMPLIANCE STATEMENT

TITLE VI, CIVIL RIGHTS ACT OF 1964; THE MODIFIED COURT ORDER, CIVIL ACTION 5281, FEDERAL DISTRICT COURT, EASTERN DISTRICT OF TEXAS, TYLER DIVISION

Reviews of local education agencies pertaining to compliance with Title VI Civil Rights Act of 1964 and with specific requirements of the Modified Court Order, Civil Action No. 5281, Federal District Court, Eastern District of Texas, Tyler Division are conducted periodically by staff representatives of the Texas Education Agency. These reviews cover at least the following policies and practices:

(1) acceptance policies on student transfers from other school districts;

(2) operation of school bus routes or runs on a non-segregated basis;

(3) nondiscrimination in extracurricular activities and the use of school facilities;

(4) nondiscriminatory practices in the hiring, assigning, promoting, paying, demoting, reassigning, or dismissing of faculty and staff members who work with children;

(5) enrollment and assignment of students without discrimination on the basis of race, color, or national origin;

(6) nondiscriminatory practices relating to the use of a student's first language; and

(7) evidence of published procedures for hearing complaints and grievances.

In addition to conducting reviews, the Texas Education Agency staff representatives check complaints of discrimination made by a citizen or citizens residing in a school district where it is alleged discriminatory practices have occurred or are occurring.

Where a violation of Title VI of the Civil Rights Act is found, the findings are reported to the Office for Civil Rights, Department of Health, Education and Welfare.

If there is a direct violation of the Court Order in Civil Action No. 5281 that cannot be cleared through negotiation, the sanctions required by the Court Order are applied.

TITLE VII, CIVIL RIGHTS ACT OF 1964; EXECUTIVE ORDERS 11246 AND 11375; TITLE IX, 1973 EDUCATION AMENDMENTS; REHABILITATION ACT OF 1973 AS AMENDED; 1974 AMENDMENTS TO THE WAGE-HOUR LAW EXPANDING THE AGE DISCRIMINATION IN EMPLOYMENT ACT OF 1967; AND VIETNAM ERA VETERANS READJUSTMENT ASSISTANCE ACT OF 1972 AS AMENDED IN 1974.

It is the policy of the Texas Education Agency to comply fully with the nondiscrimination provisions of all federal and state laws and regulations by assuring that no person shall be excluded from consideration for recruitment, selection, appointment, training, promotion, retention, or any other personnel action, or be denied any benefits or participation in any programs or activities which it operates on the grounds of race, religion, color, national origin, sex, handicap, age, or veteran status (except where age, sex, or handicap constitute a bona fide occupational qualification necessary to proper and efficient administration). The Texas Education Agency makes positive efforts to employ and advance in employment all protected groups.